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When O coincides with a focus, $p_1 p_2 = 0$; the force to $S = \frac{\mu}{b^3} \cdot \frac{1}{r^2} = \frac{\mu'}{r^2}$ suppose, and the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} a^{\frac{3}{2}} b^{\frac{3}{2}} = \frac{2\pi}{\sqrt{\mu'}} a^{\frac{3}{2}}.$$

When O coincides with the centre,

$$p_1 p_2 = -a^2 e^2 \sin^2 \theta,$$

where θ is the inclination of CP to the major axis, therefore

$$\text{force to O} = \frac{\mu}{r^2 (b^2 + a^2 e^2 \sin^2 \theta)^{\frac{3}{2}}}$$

$$= \frac{\mu}{r^2 (a^2 \sin^2 \theta + b^2 \cos^2 \theta)^{\frac{3}{2}}}$$

$$= \frac{\mu}{r^2} \cdot \frac{r^3}{a^3 b^3} = \frac{\mu}{a^3 b^3} r = \mu' r,$$

and the periodic time

$$= \frac{2\pi}{\sqrt{\mu}} (ab)^{\frac{3}{2}} = \frac{2\pi}{\sqrt{\mu'}}.$$

§ 14. The substance of the above paper was communicated to the Royal Astronomical Society on December 14, 1877, and an abstract appeared in the account of that meeting in the *Observatory*, vol. i., p. 268 (January 1878); but I have been prevented by other occupations from writing out the paper till now. The theorem that if a body moves under the action of a central force $\frac{\mu r}{p^3}$ the periodic time is $\frac{2\pi}{\sqrt{\mu}} p_0^{\frac{3}{2}}$ was set by me in the Mathematical Tripos, Wednesday morning, January 2, 1878 (see *Solutions of the Senate-House Problems and Riders for* 1878, pp. 41–43).

Trinity College, Cambridge,
1878, *August* 29.

On a Portable Star Finder for Altitude and Azimuth Telescopes.

By Edward H. Liveing, A.R.S.M.

The following is a description of an instrument that I invented in the early part of last year, and that I have had in actual use about twelve months.

My object in describing it is that I think it may be very useful with the altitude and azimuthly mounted reflectors so much in use among amateurs and others at the present day.

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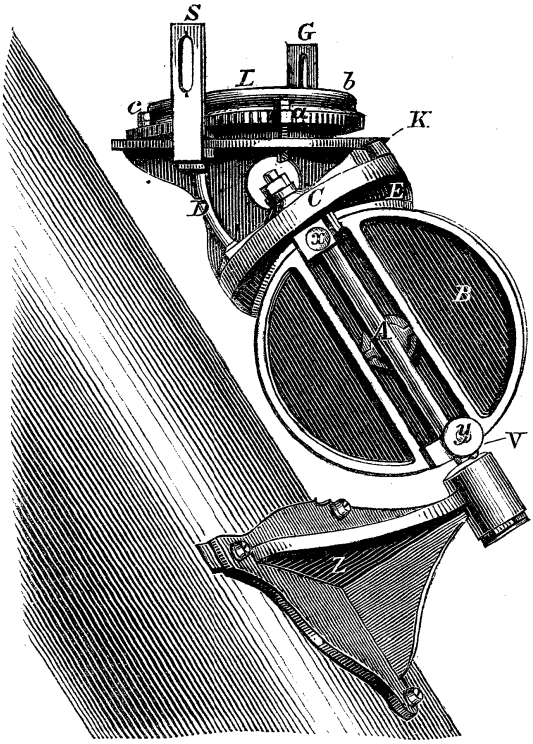
It differs from an ordinary Equatoreal in the facts that it weighs only a few ounces, and that, instead of carrying the telescope, it is itself carried by it, being employed only to direct the telescope, not to support it.

It requires no fixed or adjusted stand. The telescope and stand can be taken in and out of the house at will, and are always ready for use at once.

It enables the time to be ascertained when the Sun or any other celestial object (whose declination and R.A. are known) is visible: this it does by taking an altitude and giving the hour-angle mechanically, without calculation.

I will now, with the aid of the figure, describe its construction.



A is a spindle attached to a telescope by a bracket Z, the spindle being parallel to the optical axis of the telescope;* this spindle carries the circle B, which forms the declination circle of the instrument. This circle is movable around the spindle in the bearings x and y, but its plane remains parallel to the spindle, and therefore to the telescope. Upon the flat surface of this circle moves a brass plate E, carrying at one end a vernier V to read the graduated edge of the declination circle, and at the other the hour circle C of the instrument. Upon the surface of C turns the colatitude bracket D, carrying a vernier K to read the hour circle, and also a circular spirit level L, and two sights,

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* See mode of adjustment at end of Paper.

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S and G, clamped upon its edge and capable of being secured in any desired position.

Now, before the instrument can be used to find objects, an azimuth mark must be fixed upon, and, for simplicity of description, we will suppose some distant well defined terrestrial object to be visible from the situation where the telescope stands.

Then, to fix the sights, proceed thus:—Set the declination vernier to the declination of the Sun at the time; now direct the telescope to the Sun, so that that object is in the centre of the field; next render the circular spirit level true by moving the hour circle motion, and also the whole instrument about the spindle A. This done, adjust and clamp the sights so as to bisect the distant object fixed upon;* now read the hour circle, which gives the hour angle of the Sun at the moment, which, added to the Sun's R.A. = the sidereal time. To this having set a clock or watch, we are ready to find any object with the instrument in the following manner:—

Set the declination vernier to the declination of the object and the R.A. vernier to its hour angle (that is the sidereal time – the right ascension); now render the level correct by moving the telescope in altitude, and also the instrument on the spindle A; this done, move the telescope in azimuth until the sights bisect the distant object, and if all is done right the star will be in the field.

And conversely, if it be required to determine the R.A. and declination of a body for identification, proceed thus:—turn the telescope on the object, noting the sidereal time; move the instrument so that the level is true and the azimuth object bisected by the sights; read the declination circle, which gives the declination of the object, and the R.A. circle, which gives the hour angle of the object, which – the sidereal time = its R.A.

Now supposing no distant terrestrial object suitable for an azimuth mark to be visible from the situation where the telescope stands, the following method may be employed:—

At any convenient distance and direction fix up horizontally two deal laths, in such a manner that a line joining them passes through the place where the telescope stands. This done, direct the telescope as before described to the Sun, setting the instrument to his declination and moving until level; then fix the sights so that they cut the laths near the middle when looking backwards or forwards through them; now mark the points on

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* In fixing azimuth marks in the manner described by aid of the Sun or other celestial object, it is well to choose a time when their altitude is changing pretty rapidly, and not when near the meridian; if, however, the local time is known, this restriction is not necessary, as in that case the R.A. circle may be set to the hour angle of the Sun in addition to setting the declination circle to his declination; indeed, in any case when the time is known, it is well to do this, as it insures increased accuracy in fixing the azimuth marks.

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the laths where they cut, and mark off also a rough scale of equal parts on both sides from these central marks. The object of these double azimuth marks is to avoid parallax, and their use is very simple : thus, in the case of finding an object, proceed as before directed so far as regards setting to declination and hour angle and setting the instrument level; then, looking through the sights, move the telescope in azimuth until the central mark on one of the laths is cut; now, looking backwards through the sights, note at how many divisions from the central mark they cut the lath; reduce them to half* the number by moving the telescope in azimuth; the line of sight is now parallel to the line joining the central marks on the laths.

It will be seen that the telescope can be set down anywhere between the laths and is ready for use at once.

In the above account I have avoided going into detail so as not to confuse the description, but it is desirable I should mention a few points I have omitted.

First as to the dimensions of the instrument: one made with 2-inch circles will, I think, be found the most useful size; circles of this size can be made to read to 2″ of arc; it is of great importance that the declination circle be well graduated.

Secondly as regards the sights employed: I have found the simple form of slit and wire sights, such as are used for compasses, to answer very well; they will read either way nearly equally well, that is with the slit next the eye (the ordinary way of using them) or with the wire next the eye; in the latter case, however, the distance between them must not exceed a few inches, as it renders the field of view so inconveniently small when looked through in the reverse direction. With 3 inches distance between the sights they will read to 4′ or even less without difficulty.†

Of course, if greater accuracy is required, it can be obtained by the use of a small telescope, about 4–5 inches long and $\frac{3}{8}$ in. aperture, resting in Y bearings, which take the place of the sights.

There are certain positions of the instrument where a small reflector or reflecting prism is required to enable the sights to be seen through.‡

I should mention the whole instrument can be made to lift off the steel spindle, so that when not in use it can be kept in its own case, the necessary friction to the motion upon the spindle being given by the clamp screw *y*.

The circular spirit level is adjusted by the three screws *a*, *b*, *c*, which give a certain amount of adjustment in latitude. It could

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* That is if the telescope is about equally distant from both laths; if not, so move the telescope in azimuth that the sights cut the laths at an equal number of divisions on the same side from the central marks.

† With 5 inches distance between the sights I have found 2′ the maximum error in directing.

‡ Except when the instrument is attached to the telescope near the open end; there, however, it upsets the balance unless counterpoised, and the parallax is greater, and therefore longer deal laths are required.

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be easily made adjustable to any latitude, if desired, by having a suitable movement between the level and R.A. circle.

It may be well to state that the instrument shown in the illustration, must only be considered a temporary one, made for the purpose of trying how the method worked, and in several points I think its construction might be improved.

Lastly, I must not forget to mention two suggestions made by my friend Mr. C. V. Boys, namely, having two R.A. circles, and driving the colatitude bracket upon the upper circle by watch-work placed in the bracket and regulated to sidereal time; to find an object it would then only be necessary to set the second hour circle to the R.A. of the object, as with an ordinary Equatoreal provided with double hour circles.

The other suggestion was the addition of a small graduated circle to the movement about the steel spindle, by which addition it would be possible, using an ordinary position angle micrometer on the telescope, to obtain position angles of double stars &c.—the readings of the small circle on the spindle being added to or subtracted from those of the micrometer to obtain the true position angle of the double star observed.

The following are the various adjustments of the instrument, though most should be performed by the maker:—

(1) To determine if the plane of the declination circle be parallel to the axis of the spindle A:—

Place a spirit level on the flat surface of the declination circle (having removed the rest of the instrument) parallel to the direction of the spindle, and level by moving the telescope in altitude; turn the circle through 180° about the spindle; now, placing the spirit level on the opposite face,* observe if it still shows level; any deviation = twice the error.

(2) To ascertain if the R.A. circle is at right angles to the declination circle:—

Having removed the colatitude bracket D and placed a level on the face of the hour circle C parallel to the face of the plate E, move the spindle A and the declination motion until the level shows true during a complete revolution of the instrument around the spindle A. On removing the level and placing it at right angles to the plate E, it will exhibit if the planes of the two circles are at right angles or not.

(3) To determine the index error of the declination circle:—

The instrument being in the position just mentioned, read the declination vernier; the amount that this reading differs from 90° = its index error.

(4) To determine and correct the index error of the R.A. vernier:—

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* This supposes the two faces have been turned up parallel to each other.

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The spindle A being still as in the last adjustment, truly vertical, put on the colatitude bracket D, and move the R.A. and declination motions till the circular level is true, then the R.A. circle should read 0^{h}; if not, adjust the level by the screws *a* and *b* until it does.

(5) To adjust the level to the angle of colatitude of the place of observation:—

The spindle as before being vertical, the R.A. vernier at 0^{h}, and the declination vernier set to the colatitude, adjust the level true by the screw *c*.

(6) To set the spindle parallel to the optical axis of the telescope:—

Set up a scale of equal parts vertically at a distance of 200 yards or so from the telescope, and having placed a spirit level on the surface of the declination circle, parallel to the direction of the spindle (as in the 1st adjustment), move the telescope till it shows level; read scale through telescope; now reverse the telescope, level again as before, note reading of scale again; the midway point between these two readings is the level point; to which having set the telescope, adjust the spindle level by the screws that hold it; now support the telescope on temporary supports the same height as its stand, with the line joining its trunnions vertical, and having directed it to the level point on the distant scale, adjust the spindle level in this direction also.

Note upon the Star Bradley 2935. By Prof. T. H. Safford.

(*Communicated by the Astronomer Royal.*)

The star in question, the *preceding* of a double found in Struve's Dorpat Catalogue, has usually been identified with the *following* component; and this because its proper motion for 100 years is approximately equal to the distance between the two stars.

How the case stands can be readily seen by reducing the extant positions of the preceding star to 1855·0. With the approximate position for that date,

$$22^{h}\ 3^{m}\ 11^{s}.2 \quad \text{and} \quad +82^{\circ}\ 10'\ 13'',$$

we obtain the following formulæ for reduction (by precession only) from 1855 to 1855 + *t*:—

$$\text{In R.A.} \qquad -1^{s}.67298\,t - 0^{s}.3972\,\frac{t^2}{200} - 2^{s}.017\left(\frac{t}{100}\right)^3,$$

$$\text{In Decl.} \qquad +17'.5053\,t - 0''.1274\,\frac{t^2}{200} - 0''.511\left(\frac{t}{100}\right)^3,$$